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Surface and subsurface manifestations of gas movement through a N–S transect of the Gulf of Mexico

Jean Whelan[a,*], Lorraine Eglinton[a], Lawrence Cathles III[b], Steven Losh[b], Harry Roberts[c]

[a]*Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, 266 Woods Hole Road, MS #4, Woods Hole, MA 02543, USA*
[b]*Department of Geological Sciences, Cornell University, Ithaca, NY 14853, USA*
[c]*Coastal Studies Institute, Louisiana State University, Baton Rouge, LA 70803, USA*

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Abstract

Large volumes of gas have vented through a north–south transect of the offshore northern Gulf of Mexico. An overview of surface and subsurface manifestations of this gas venting is presented. This gas movement has caused extensive alteration of reservoir oils to the north of the transect which are estimated to have equilibrated with, or been gas washed by, as much as 30 volumes of gas for every volume of oil. This gas washing entrains and carries upward the most volatile oil components depositing them in either shallower reservoirs or venting them to the overlying sediments and the water column. A significant amount of this gas bypasses the reservoirs and vents upward into the overlying sediments and waters. In spite of the significant amounts of the gas involved, the venting at the seafloor appears to occur primarily through highly localized faults and fractures. This gas discharge is spatially and temporally heterogeneous, making it difficult to estimate the actual hydrocarbon fluxes involved. This upward gas movement leaves characteristic signatures at the sediment water interface including carbonate pavements in older seep areas, and chemosynthetic biological communities, methane hydrates, and gas seeps in more recent long-term seep areas. In some cases where gas venting is very recent, massive disruption of surface and subsurface sediments is observed to be occasionally accompanied by mud volcanoes. Venting can be vigorous enough to produce methane gas bubbles, which appear to be injected rapidly into surface waters and which may constitute a significant source of methane, a greenhouse gas, to the atmosphere.

In the northern Gulf of Mexico, gas venting is sometimes accompanied by natural oil slicks at the sea surface, which can be tracked for many miles in non-productive areas. These gas-venting signatures are not unique to the Gulf of Mexico; similar seep features are observed in sediments worldwide. The widespread occurrence of these seep features, which may or may not be related to subsurface oil and gas deposits, may explain why use of surface seeps has often proved to be so controversial in oil exploration. Indeed, most seeps are probably not linked with economic subsurface petroleum reservoirs.

The relationships between surface seep features and productive subsurface reservoirs along a N–S transect of the northern Gulf of Mexico are presented as an example of how all surface and subsurface geochemical, geological, geophysical data might be used together to better constrain interpretations regarding the nature and dynamics of subsurface oil and gas deposits and their plumbing in frontier areas.

Keywords: Methane; Hydrate; Seep; Migration; Petroleum; Gas; Biodegradation

1. Introduction

The goals of this paper are to present an overview of the dynamic nature of gas movement along a north–south transect in the northern Gulf of Mexico (Fig. 1); demonstrate the apparent relationship between subsurface gas movement and surface sediment seep features, and; show how these processes might impact interpretations of surface seepage as related to the presence of underlying gas and oil reservoirs. The effects of Gulf of Mexico gas movement on subsurface oil reservoirs, surface sediments, the water column, and the overlying atmosphere are summarized. The manifestations of dynamic gas movement described here are not unique to the Gulf of Mexico. Examples of similar seep features in other geographic areas worldwide are presented to demonstrate that surface

* Corresponding author. Tel.: +1 508 289 2819; fax: +1 508 457 2164.
E-mail address: jwhelan@whoi.edu (J. Whelan).

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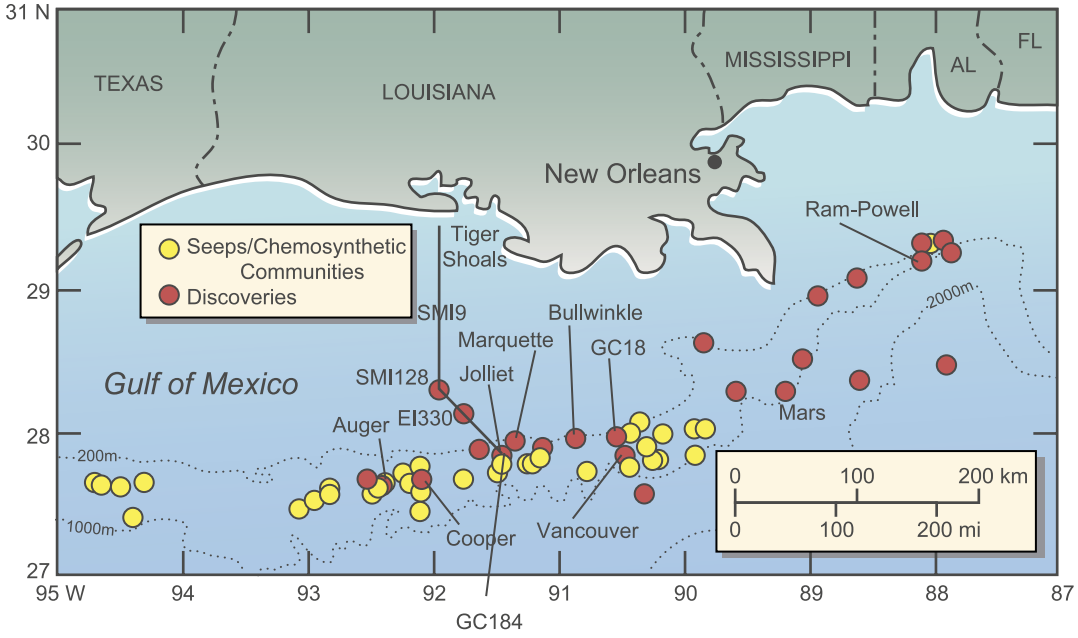

Fig. 1. Map of oil and gas seeps/chemosynthetic communities and recent petroleum discoveries (adapted from Sassen et al., 1993a,b). The location of N–S well transect on upper slope of northern Gulf of Mexico is indicated by the heavy black line.

seepage occurs very widely in some parts of the ocean floor, particularly along the edges of continents and in ocean margins, even when no viable producible petroleum reservoirs appear to be present. The widespread occurrence of these seep features, which may or may not be related to subsurface oil and gas deposits, may explain why use of surface seeps has often proved to be so controversial in oil exploration. The relationship between the surface seep features and subsurface gas migration through reservoirs along a N–S transect in the Gulf of Mexico is presented as one example of the relationship between surface seep geology, chemistry, and biology, and the dynamics of subsurface gas and oil movement into and through subsurface petroleum reservoirs.

2. Summary of effects of gas venting in the northern Gulf of Mexico

Extensive research has been carried out in the offshore Green Canyon (GC184) area of the upper continental slope of the northern Gulf of Mexico (Fig. 1) near the Conoco Jolliet oil field. Extensive work has been carried out in this area, including mapping seafloor gas and oil seep features (Fu and Aharon, 1998; Aharon et al., 1997; Brooks et al., 1984, 1986, 1987, 1990; Kennicutt et al., 1985, 1988a,b; Paull et al., 1989; Roberts et al., 1990a,b; 1999a,b; Roberts, 2001; Roberts and Carney, 1997; MacDonald, 1998; Milkov and Sassen, 2003a,b), the study of biology of chemosynthetic communities associated with the seeps (Brooks et al., 1987, 1990; Childress et al., 1986; Fisher et al., 1987; Kennicutt et al., 1985, 1988a,b; MacDonald and Joye, 1997; MacDonald, 1998; MacDonald et al., 1994, 1990a,b; Sassen et al., 1993a,b, 1994a,b, 1998, 1999a,b; Zhang et al., 2002, 2003), and surface gas hydrates (MacDonald et al., 1994; Roberts, 2001; Roberts et al., 1999a,b; Sassen and MacDonald, 1997; Sassen et al., 1993a,b, 1998, 1999a,b; Sassen, 2001, 1999; Lanoil et al., 2001). The study area lies within a broader general area of natural oil and gas seeps encompassing much of the upper continental slope of the Gulf of Mexico (Fig. 1). These natural seeps are closely related geographically, with productive subsurface reservoirs, as shown in Fig. 1 (adapted from Sassen et al., 1993b). A summary of surface and subsurface phenomena associated with the northern Gulf of Mexico gas seeps is shown schematically in Fig. 2. These venting features produce a substantial oil and gas flux into the overlying water column as shown by huge oil slicks over non-oil productive areas described by "MacDonald (1998) and MacDonald et al., (1993, 1996, 2002). The volumes of oil and gas vented to the water column and to the atmosphere are probably substantial, as discussed further in Kvenvolden and Lorenson (2001), Kvenvolden and Rogers (2005) and Judd et al. (2002). The venting also causes significant alterations to subsurface sediments, which can be observed seismically (e.g. Fig. 3 from Hunt, 1996) and in short-term changes in the compositions of oils in reservoirs, as discussed later in this chapter.

The interest of Cornell University and the Woods Hole Oceanographic Institution in this area began with a project to study subsurface migration of oil and gas along the N–S Gulf of Mexico transect, shown in Fig. 4. The most surprising overall conclusion of that study was that long-term dynamic gas migration occurring throughout